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PHYSICS OF THE ATMOSPHERE
RESPONSE OF THE WATER VAPOR CHANNEL OF THE METEOSAT SATELLITE

by

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16. Abstract

An accurate model of the atmospheric transmission function is used to obtain the relationship between the cloudless radiances measured by the 6-7μ Mêtêosat radiometer ("water vapor" channel) and the numerical parameters associated to each point of an image. This relationship is compared to the temporary calibration curve published by the European Space Agency.

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PHYSICS OF THE ATMOSPHERE
RESPONSE OF THE WATER VAPOR CHANNEL OF THE METEOSAT SATELLITE

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Meteosat is the first geostationary satellite equipped with a radiometer to possess a channel centred on the band of absorption of water vapor (5.6 to 7.5 μ). This satellite provides an image of a given geographical region every half hour. The development in space and over time of masses of water vapor can thus be observed on the basis of consecutive images. The satellite observations in this spectral field have, up to the present, been carried out only by satellites with a polar orbit such as certain Tiros and Nimbus satellites, supplying at most two images per day of a given geographical zone. The radiant energy measured above cloudless zones (especially in the absence of cirrus) in the water vapor channel can be linked to the average relative humidity of the middle troposphere. In this region, where water vapor can be considered as a tracer of atmospheric movements, qualitative dynamic studies have also been carried out, using radiometric data [5], [6], [7] /325

A truly quantitative analysis of the radiometric data of the water vapor channel of the Meteosat satellite is possible only if the calibration for this channel is available. The signal received by the radiometer appears on the magnetic recording tape in the form of a numerical value coded between 0 and 256. The calibration makes it possible to find out the relationship between this coded value and the radiant energy received by the radiometer. This calibration is not available for the Meteosat water vapor channel and can only be realized *a posteriori* by indirect methods. Up to the present, the European Space Agency has published only a temporary calibration curve [8].

*Numbers in the margin indicate pagination in the foreign text.

It was possible to obtain this relationship by computation using the equation of radiative transfer which links the radiant energy received by the radiometer to the meteorological parameters of the atmosphere. These calculations were carried out for specific geographical points, selected on the basis of the existence of complete temperature, pressure and humidity surveys; the results are compared to the values of the numerical variable associated with each point of a cloudless image. The calculations were carried out using a line by line transmission model presently installed in the laboratory. Starting with spectroscopic data of absorbing molecules in the spectral interval defined by the filter of the radiometer, this model makes it possible to calculate, at a very high resolution, the functions of atmospheric transmissions, then the radiances by convolution with the function of the apparatus. This model for the calculation of transmissions and atmospheric radiances has been described in detail in two previous publications ([19], [10]): it is based on direct altitude
325/ and frequency integration and on the use of parameters of the fine structure of the absorption lines. To adapt the general model to this particular problem, we made a preliminary study of a Thir image from the Nimbus-5 (of which the calibration was known). The values of radiant energy which we calculated were in agreement with the experimental values (see the table in reference [11]).

In both cases, for the Thir channel of Nimbus-5 and for the water vapor channel of Meteosat, the transmissions were calculated with an integration interval of $2.5 \cdot 10^{-3}$ cm^{-1}, the average value of the Doppler half-width of the water vapor lines at the highest altitude. The form of the line is taken into account up to 100 times the half width at mid-height from the center of the line. In the spectral field defined by the Meteosat water vapor channel (1,342 cm^{-1} - 1,774 cm^{-1}), water vapor can be considered the only absorbant gas. The atmosphere is divided into 20 layers divided into pressure levels between 1,000 and 5 mb. The intensities of radiation emitted (I) are calculated by the equation of radiative transfer at intervals of 0.5 cm^{-1} so as to obtain a correct representation of the Planck and filter functions.

Table

14 JUL. 1978						16 JUL. 1978		
STATIONS	I $Wm^{-2}sr^{-1}$	VALEUR[1]	STATIONS	I $Wm^{-2}sr^{-1}$	VALEUR[1]	STATIONS	I $Wm^{-2}sr^{-1}$	VALEUR
AJACCIO	1.09	117	IDRIS	1.17	145	AJACCIO	1.00	117
BELFAST	0.77	77	LISBONNE	1.13	145	LISBONNE	1.11	121
BELGRADE	1.00	105	LYON	0.90	105	MALTE	1.18	148
BORDEAUX	0.97	117	MALTE	1.19	137	NIMES	1.00	109
BREST	0.74	89	NIMES	0.94	109	ROME	0.96	109
FUNCHAL	1.15	129	UDINE	0.87	85	TUNIS	1.26	154
GIBRALTAR	1.15	141						

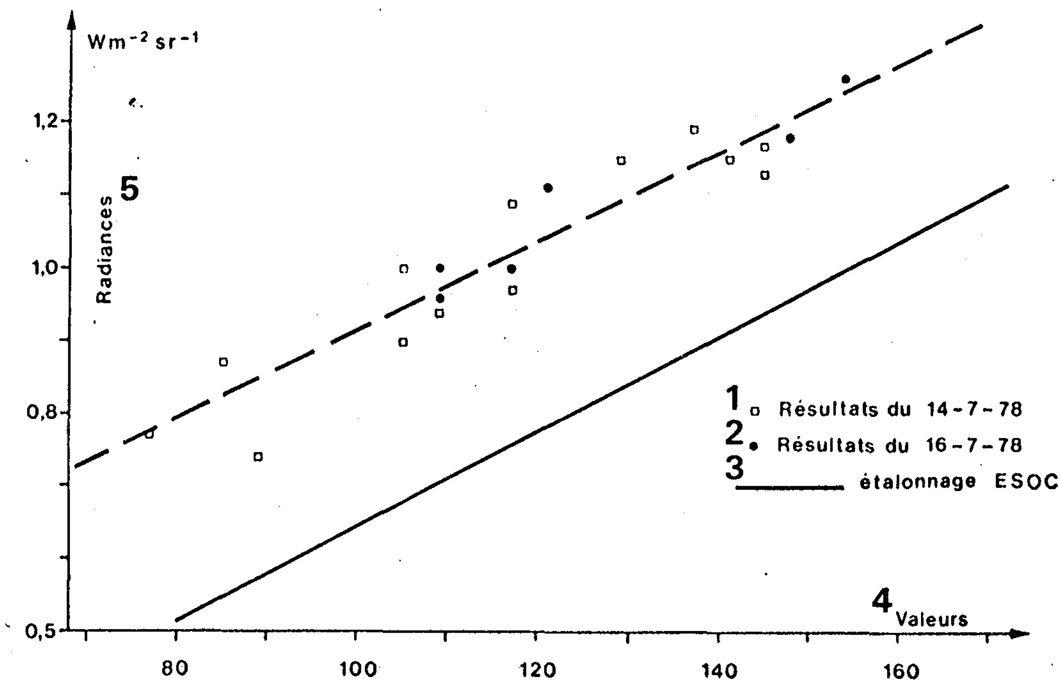
Key: 1. Value

We used the photographs from the 14th and 16th of July, 1978, at 1200 hours GMT, in the geographical zone extending from 30°N to 55°N and 20°W to 25°E, that is, roughly the western part of Europe and the Meditarranean Basin. During this period, the radiometer detector was maintained at 90 K and the corresponding apparatus function was introduced into the computations. In the geographic zone under study, stations of the international meteorological system are relatively numerous. Cloudless atmospheric data are supplied by radiosondage. The subsatellite point of Meteosat is located at 0° latitude and /326
longitude, therefore, for the selected geographical region, the angle

made by the direction of the satellite with the zenith of the station is relatively large (of the order of 50^{o}). Two consecutive points of an image are therefore separated by a ground distance of about 8 km. The quantity of absorbing water obviously depends on the angle with the direction of the zenith and this was taken into account in a precise fashion for each of the stations under consideration. The laboratory has at its disposal an interactive system of image visualization which makes it possible to locate the radiosondage stations. A certain number of landmarks are located on the corresponding image in the visual channel and a navigation program, taking into account the parameters of the position of the satellite, makes it possible to locate the stations with an uncertainty of better than four image points. The distance corresponding to these four points is of the order of size of the average horizontal trajectory of a radiosondage balloon during its ascent to the tropopause.

For each station located on the photo, we read the value of the numeric variable associated with it and compare this value to the radiance calculated on the basis of the meteorological parameters obtained by radiosondage. The results are given in the table and represented in the figure. The calculations were carried out for 19 stations. The number of cases studied was limited by the restitution time of the model (of the order of 0.7 seconds for 1 cm^{-1} with an "IBM 370/168" computer) and by the relatively small number of cloudless surveys available. The dispersal of points around the straight line average - obtained by linear regression - comes principally from uncertainties on the atmospheric profiles (temperature, humidity) and on the geographical location of the stations on the image. The straight line average is almost parallel to the temporary calibration curve, obtained by a different method, published by the European Space Agency. Errors on the calculated values of transmissions and atmospheric radiances cannot be responsible for the discrepancy between the two straight lines, a discrepancy which, converted into
327/ equivalent temperatures, represents about 8 K.

At the end of 1979, a new calibration will be carried out on board the satellite by means of a sighting on the moon and should provide a new basis for comparison. Moreover, we will use these results for a three dimensional, quantitative study of the water vapor field in cloudless conditions in middle and tropical latitudes.



Key:
1. Results of 7/14/78
2. Results of 6/7/78
3. Calibration of ESOC
4. Values
5. Radiances